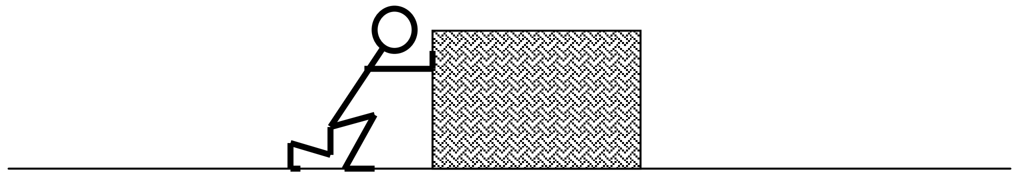
Forces and Newton's Laws

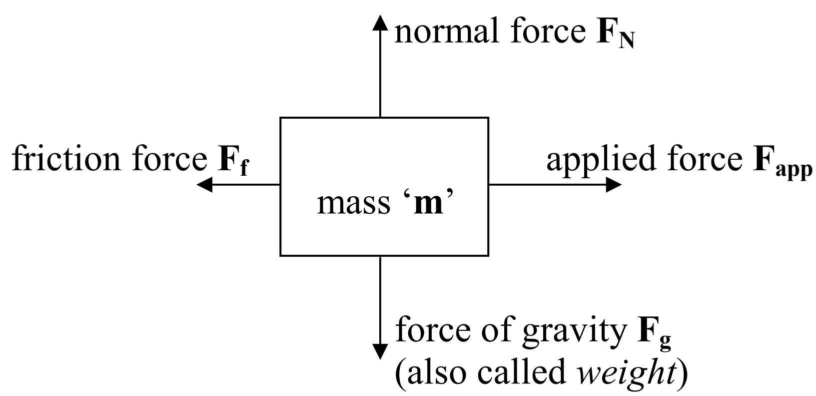
A *force* is simply a push or pull of one object on another object. Two objects are needed for a force to occur: one object applies the force, while the other object has the force applied to it. For example:



- In this system, a student (object 1) applies a force to the right, which acts on the crate (object 2).

Since a force can be directed one way or another, it is a *vector* quantity, with symbol 'F' and units being the *Newton*, or 'N'.

Typically, only the object that has forces acting on it is analyzed in a physics problem. The analysis is represented as a *free-body diagram* that isolates the object in question and shows all the force vectors acting on it. In the diagram above, there are four forces that act on the crate:



These are some typical forces that you should know from Physics 11. Note that:

- the friction force always acts to oppose motion, and may or may not be as large as the applied force. It is always *parallel* to the surface upon which the object is resting or moving.
- The normal force is a pressing force between object and surface. It always acts *perpendicular* to the surface upon which the object is resting or moving.
- The friction force and normal force vectors are always perpendicular to each other.

As a branch of physics, *dynamics* is the study of the causes of motion, and is explained by Newton's three laws of motion.

- **First Law:** Every mass has *inertia*, which is the tendency of the object to resist any change in its state of motion (i.e. resist any acceleration). Therefore, if the *net force* on an object is zero, two things can happen:
  - if the object is stationary, it will remain at rest.
  - if already in motion, the object will continue to move at a constant speed in a straight line. This is *uniform motion*.

  In either case, because $\mathbf{F_{Net}} = 0$, all forces in a free-body diagram must "cancel" out; i.e., there is no resultant vector.

- **Second Law:** This law explains an object's motion when the net force acting on it is not zero. This net force will cause the object to *accelerate*. The rate of acceleration depends on force and mass as follows:

  $$\mathbf{a} \propto \mathbf{F_{Net}} \quad \text{and} \quad \mathbf{a} \propto \frac{\mathbf{1}}{\mathbf{m}} \quad \rightarrow \quad \mathbf{F_{Net} = ma}$$

  Note that since $\mathbf{F_{Net}}$ exists, the vector-sum of all forces in a free-body diagram will reveal a resultant vector.

- **Third Law:** Whenever one object exerts a force on a second object, the second object exerts an equal but opposite force on the first object. This is the action-reaction effect: the *action* is applied on one object, but the reaction is applied back on the first object. Normal and friction forces are examples of reaction forces.

Example #1. An 8.0 kg mass is pushed along a horizontal surface at constant speed with a force of 24 N.

a) Draw a f.b.d. showing all forces that act on the mass. Include the value for each force drawn.

b) The same 8.0 kg mass is now pushed with a force of 37 N. Find the acceleration of the mass.

(see Dynamics Ex 1 for answer)